UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

SAFETY EVALUATION REPORT

ONCE-THROUGH STEAM GENERATOR REPAIR AND AUXILIARY FEEDWATER SYSTEM MODIFICATIONS

TOLEDO EDISON COMPANY

AND

CLEVELAND ELECTRIC ILLUMINATING COMPANY

DAVIS-BESSE NUCLEAR POWER STATION, UNIT 1

DOCKET NO. 50-346

1.0 Introduction

While conducting inservice inspection of the No. 1 steam generator during a scheduled refueling outage, the licensee noted that some of the eddy current indications being obtained for the peripheral tubes appeared to correspond to the locations of some of the support pins which hold the internal auxiliary feedwater header to the steam shroud. Other indications were also obtained which corresponded to the approximate elevation of the auxiliary feedwater header. An access cover on the steam generator shell was removed to permit limited direct visual inspection of the auxiliary feedwater header. The header and some support brackets were observed to be severely distorted, although the header remained in its approximate position. Further limited inspection using a fiber optic device confirmed that the damage generally extended over the entire portion of the header accessable to the fiberscope, approximately a 160 degree segment of arc. Subsequent inspection of the No. 2 steam generator revealed similar damage.

The extent of the damage to the auxiliary feedwater (AFW) header, support system and the sleeve connecting the feedwater nozzle to the header is detailed elsewhere (1)(2).

Following the discovery of the damaged steam generators at Davis-Besse, inspections were conducted at Rancho Seco and Oconee 3, the only other operating plants having a similar AFW internal header. Similar damage at both these plants was also discovered.

2.0 Discussion

By letter of July 15, 1982 (No. 839)(2) and August 6, 1982 (No. 845)(4) Toledo Edison Company (TECo) has submitted information related to the repair of the damaged internal AFW headers and modifications made to the AFW system. Supplemental information has been submitted by TECo letter dated August 16, 1982 (No. 849)(4).

The repair and modification program selected by TECo involves a modified system for auxiliary feedwater injection and distribution and deactivating the existing AFW header, leaving the retired header in place. The retired header is to be securely fastened to the steam shroud to prevent subsequent damage to the tubes.

The design uses an external header fabricated of 6 inch pipe which encircles the steam generator shell for about 300 degrees. Eight 3-inch pipe risers, spaced around the ring, feed AFW through the steam generator shell and shroud to the secondary side of the tubes. To allow for injection of AFW into the steam generator, it was necessary to bore eight 5-inch diameter holes through the steam generator shell. The same size hole was bored through the shroud, in line with the hole in the shell. The pipe risers are flanged and bolted to the shell.

The centerline of the riser inlet to the steam generator will be located about 14 inches above the top tube support plate. A tapered thermal sleeve will direct the flow from the shell opening through the shroud to the steam generator secondary side. Each riser will contain an orifice at the flange in the vertical run to help equalize distribution of flow.

This design is similar to that used at five operating B&W plants except that 1) the point of injection of AFW is approximately 3 inches higher than in the earlier designs, 2) the Davis-Besse modification uses orifices in the risers, and 3) the feed to the risers in the Davis-Besse modification is nearer the midpoint of the external header.

The damaged internal header has been solidly secured in place to continue to function as an extension of the tube bundle shroud; however, it will no longer function as part of the AFW system. At eight locations around the circumference, corresponding to the location of the 5 inch holes bored into the steam generator shell, the bottom of the internal header has been secured to the shroud with a 7 inch long fillet weld. Additional support has been added at these locations using gusset plates welded to the shroud and the bottom of the header. The original nozzle, used to deliver AFW to the internal header, is blocked with a blind flange.

Access to the internal AFW header, header supports and feedwater nozzle is through one 16 inch access port and the eight 5 inch holes bored through the shell and shroud. Because of this limited access, only a small portion of the header could be inspected by direct visual means. Most of the inspections have been through the use remotely operated video cameras and fiber optic devices.

Inspection of the damaged internal AFW header system revealed that a number of the header support brackets were torn out and many of the dowel pins out of position. TECo has attempted to locate and remove all loose parts and, except for one dowel pin, all known loose parts have been removed from the steam generator. The licensee has stated that the existing Vibration and Loose Parts Monitoring System on the steam generators is not considered reliable for detecting loose parts on the secondary side of the steam generator.

All critical areas of the header, header supports, AFW nozzle, and steam generator shell have been inspected by one or more methods, except for the inner corner welds of the internal heder. The inspection techniques used were:

1) Limited direct visual
2) Remote video with 3 to 5 times magnification
3) Fiber optics with 3 to 5 times magnification
4) Ultrasonic (UT)
5) Dye Penetrant (PT)

Only about 25% of the lower inner corner welds and about 13% of the upper inner corner welds of the header could be inspected. These weld areas were inspected using fiber optics.

The inspections of the critical areas did not reveal any indications that could cause degradation of the structural integrity of the shell, shroud, or internal header (once the header is securely fastened to the shroud).

3.0 Evaluation

3.1 Cause for Header Damage

The licensee has considered several mechanisms as the possible cause of the deformation to the internal headers, but he has concluded that the most likely cause is rapid condensation-induced high pressure differental. Stress calculations performed by the licensee concluded that a pressure differential in excess of 200 psi is required to cause collapse of the internal headers. We agree with the licensees assessment that rapid condensation-induced pressure differential is the most likely cause of the collapse.

The design of the internal AFW header was such that during operation of the plant, prior to AFW actuation, the header would be filled with steam. When AFW is actuated, there would be a sufficient flow of subcooled water which would result in a rapid condensation of trapped steam, with attendant depressurization, inside the header. We also conclude that the rapid flooding of the header with cold AFW when the steam generator is at operating conditions produces high thermal stress which could contribute to the distortion.

The modified AFW system is similar in design to systems used at five other B&W operating plants with more than 22 reactor years of operation without any evidence of water hammer or condensation induced pressure surges. Additionally, the modified AFW risers and external header will not be insulated to insure that the risers and header ring will remain filled with water.

The external AFW header will facilitate visual inspection of the AFW piping and thereby readily identify any damage due to rapid condensation induced high differential pressure.

Appendix C of the licensee's submittal(2) provided responses to the staff's request for additional information(5) which was dated June 23, 1982. Item 11 of the staff's June 23 letter requested a description of the water hammer test to be performed prior to resumption of power operation. In the licensee's submittal dated August 6, 1982(2), the licensee committed to perform a water hammer test before criticality. Therefore the requirements of General Design Criterion 4, "Environmental and Missile Design Bases", and the guidelines of NUREG-0800, Standard Review Plan, Section 10.4.7, "Condensate and Feedwater System" and Branch Technical Position ASB 10-2, "Design Guidelines for Water Hammers in Steam Generators with Top Feedring Design" with respect to the dynamic effect associated with possible fluid flow instabilities, are met.

3.2 Modified AFW System

As previously stated, the modified AFW system is similar to designs which have been in service for 22 reactor years. The modified design differs from the inservice design in two respects: slightly higher elevation of AFW injection and use of flow equalizing orifices. The latter feature will result in a higher AFW flow resistance. Toledo Edison stated (3) that a cold AFW flow test would be performed to verify AFW flow. In a submittal dated August 6, 1982(2), the licensee agreed to perform a hot AFW flow test to verify that the minimum required flow, as identified in the licensee's submittal dated May 22, 1981(6), is provided to the steam generators. The staff has concluded that the modified AFW system is acceptable. This conclusion is based on:

(1) the similarity of the modified AFW system to proven designs,
(2) verification of required minimum AFW flow, and,
(3) the performance of a water hammer test.

3.3 Internal Header Stabilization

The extensive inspection program carried out for Davis-Besse shows about the same type of damage as was discovered at Rancho Seco and Oconee 3. Namely, the vertical wall of the header was distorted inwards towards the center of the steam generator, the support brackets were bent or damaged, and the dowel pins were either out of position or missing. As a result of this distortion, the distance between some peripheral tubes and the header had been reduced, and in some instances, contact between tubes and the internal header assembly occurred. The repair procedure at Davis-Besse included recentering the internal AFW header prior to fastening to the shroud so that the minimum clearance between any part of the header and an unplugged unstabilized tube was not less than 1/8 inch. The licensee has stated that this minimum clearance exceeds flow induced vibration and thermal motions.

The inspections performed on the Davis-Besse AFW headers did not reveal any cracking of the corner welds on the header. For the Rancho Seco Nuclear plant, the inspection program revealed, in addition to the previously described typical damage, two cracks in the header corner welds. One is approximately 20 inches long in one steam generator and the other is 15 inches long in the other steam generator. Both cracks were located in the lower inside weld which joins the inner plate to the bottom of the internal header of the steam generators.

For the Oconee plant, in addition to the previously described typical damage, extensive additional damage was observed in the B steam generator. This additional damage consists of many cracks in the attachment welds and three holes in the horizontal plates of the internal header.

In order to prove the adequacy of the stabilized header, its associated welds, and support and attachment system, the licensee has performed a three dimensional analysis where the stabilized header was modeled using the ANSYS Finite Element Code. The shroud was also modeled along with the shroud alignment pins. The analysis was performed for the appropriate load combinations of deadweight, flow induced vibration, operating basis earthquake, thermal transients, safe shutdown earthquake, LOCA, and main steam line break. It was shown from the results of the analysis that the load combination of Level D (Faulted) loads which includes the main steam line break and safe shutdown earthquake is the limiting case for the header weld analysis. Even in this limiting case, a factor of safety of 2.2 over ASME Section III code allowable stresses is obtained. This can be interpreted to mean that only 45.5% of the weld would be required to insure the structural integrity of the header provided that any damage in the weld is evenly distributed in the circumferential direction. Another analysis has been performed using the load combination of the limiting case assuming a 28 inch crack to exist in the lower inner corner weld of the header to determine its effects on the header stress pattern. The results of the analysis show that the crack does cause a slight increase on the local stresses but has no impact on the function of the header. Moreover, the largest loading on the corner weld is a moment about the tangential axis due to differential thermal expansion. Thus, the potential for crack propagation will be in the radial direction, i.e., through the wall, and not in the circumferential direction.

TECo has performed an analysis to demonstrate the adequacy of the distance between the header and steam tube bundle. It was shown that, for the limiting case, the distance is adequate to preclude damage to tubes which are no closer than the minimum distance, and that substantial margin still exists to preclude any rupture in the tubes. Furthermore, TECo has committed to inspect the stabilized internal header, the attachment welds and external header thermal sleeves through all AFW injection openings during the next two refueling outages and at the ten year inservice inspecton intervals.

Based on the results of the analysis performed for the stabilized internal header, the margin of safety associated with all loading combinations postulated to occur including an assumed crack of 28 inches, the inservice inspection carried out at each plant, and the future inservice inspection program planned for the secured header, the staff has concluded that the internal AFW header stabilization is acceptable.

3.4 Loose Parts

With the exception of one dowel pin, 3/4 inch in diameter and 2 11/16 inch long, all loose parts have been located and removed from both steam generators. TECo has examined all locations within the steam generator where it is possible for the missing pin to be located. Additionally, TECo has examined horizontal portions of the main steam lines which can be reached using available inspection means, including sending a worker into accessable portions of the steam line, and has searched for the pin in the condenser.

The staff has concluded that, based on the licensee's inspection efforts to locate the missing pin, that it is unlikely that the pin is still within the steam generator. The only safety related components down-stream of the secondary part of the steam generator are safety valves and a main steam isolation valve. The pin has not been located at any of these components. Considering that no safety related component is likely to be adversely affected, it is concluded that the plant operation without recovery of the missing pin is acceptable.

4.0 Conclusion

We have concluded, based on the considerations discussed above, that: (1) because the facility modification does not involve a significant increase in the probability or consequences of an accident previously evaluated, does not create the possibility of an accident of a type different from any evaluated previously, and does not involve a significant reduction in a margin of safety, the facility modifications do not involve a significant hazards consideration, (2) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, and (3) such activities will be conducted in compliance with the Commission's regulations and will not be inimical to the common defense and security or to the health and safety of the public.

Dated: August 20, 1982

The following NRC personnel have contributed to this Safety Evaluation: A. De Agazio, A. Hafiz, J. Ridgely.

References

(1) Licensee Event Report 82-019 Rev. 1, Toledo Edison Company, May 24, 1982

(2) Letter, Toledo Edison Co. to NRC, August 6, 1982 (No. 845)

(3) Letter, Toledo Edison Co. to NRC, July 15, 1982 (No. 839)

(4) Letter, Toledo Edison Co. to NRC, August 16, 1982 (No. 849)